Analisi dei dati derivanti da una stazione meteorologica sperimentale al fine di quantificare e proteggere la risorsa idrica nei bacini montani

alluvial deposits. The photo-interpretation has also allowed the identification of the area forms of modeling, storage and erosion related to the action of the glacier and landslides.
A comprehensive study in mountain areas can't ignore accumulation phenomena of snow in winter, its evolution and melting during spring and summer. The snowfall during the winter, doesn't contribute to runoff immediately, but snowmelt in the spring and summer months, play a important part in runoff. The data of the two springs studied have verified that the flow rates in snowmelt period constitute the most considerable event in hydrological year.
A model for the study of the snow outflows must be able to calculate the amount of melt water which becomes input of the simulation of the basin outflows. Many models have been developed at the international level, which did not always meet the operational needs. They require, in fact, many experimental data which are generally not available in the normal meteorological networks.
Installing a weather station experimental, funded by Regione Autonoma Valle d'Aosta, it was possible observe the weather climate parameters for the years 2010-2011. The data has allow to define an expeditious methodology for estimating the quantity of water (SWE) using the instrumentation of a standard meteorological station at high altitude.

FIGURA 212: THE METEOROLOGICAL STATION

This methodology uses the data from three sensors: the thermometer, the snow high and the rain gauge (this can be heated or not). Furthermore it is necessary a fourth input data: the density, this result from manual assays of AINEVA (Interregional Association Snow and Avalanche). The snow density is the only parameter to discriminate the type of precipitation.
In mountainous areas the hydrology year has been divided into two parts, the first relating to the period when the snow high registers data, and the second one concerns the remaining period.

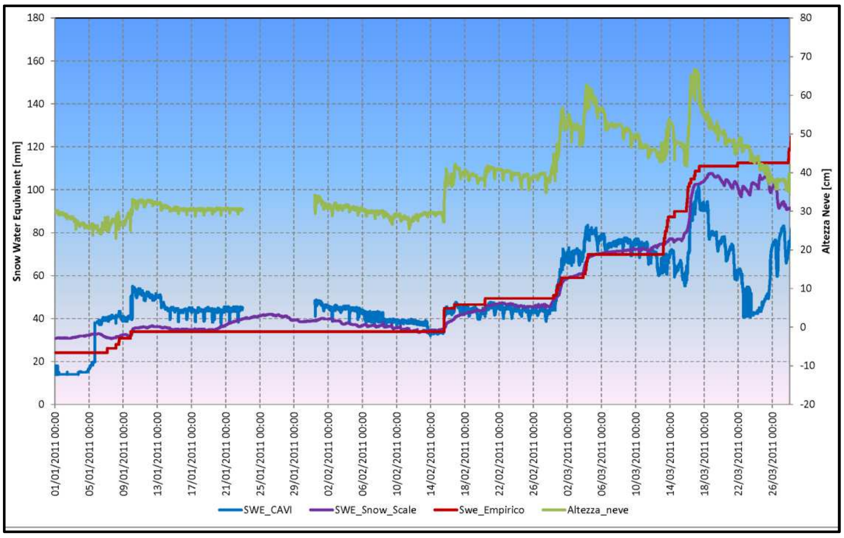


**FIGURA 213: SWE MESURED**

The installed sensors and a series of campaigns in the basin during the winter period have allowed to verify the correlations between measured data and those who returned the methodology. In fact, in the winter 2010-2011 good SWE correlations (average value of 108.75 mm with a standard deviation of 7.63) was gained.

Then it was possible to define the most appropriate one among the different instrumentations for snow cover monitoring in high-altitude stations. The solution proposed here involves the installation of: a thermometer and a hygrometer, snow high and a buried rain gauge.

The approach used in the Mascognaz Valley has been extended on many stations of the Mid-Lower Valle d'Aosta with good correlations between rainfall-height and temperature-height have been obtaining. These correlations have allowed to apply inverse hydrogeological balance method.

Furthermore, a isotopic study on samples of different snowfall in the basin has been possible identifying, during the winter 2011-2012, the source of the snow disturbance. The isotopic values of snow which were analyzed and after compared with global meteoric (MWL) and the Mediterranean (MMWL) precipitation line.

This comparison shows that the samples are on MWL line. They are a meteoric origin without effects due to isotopic fractionation or mixing. In addition these are an Atlantic source because during the density survey has been measured very low values of this.

The installation of two probes has allowed to monitor the two springs in the Valley. Through water samples has determined chemical and isotopic characteristics. In conclusion the vulnerability and protection areas of the springs are defined.

Isotopic values of the spring samples (Mascognaz 1 and Mascognaz 2) are very similar to the stream, this correlation is supported by comparison with chemical data and system capacity.

Mascognaz 1 is more affected by the influence of precipitation in the charging phase and it has a variability index equal to 91.17% which places it among the springs sub-variables and it is very close to the limit of 100% of the variable springs. While, Mascognaz 2, in contrast to the previous one, is not part of the original uptake and it is totally in aquifer. The flow is very smooth and it is more affected by the influence of the river. This is also confirmed by the variability index that is only 9.04% of constant springs. Furthermore, from a study of the springs hydrographs, Mascognaz 2, in dry periods, has a flow rate 5 times lower than Mascognaz 1.

Through the application of three different methodologies for the study of the spring vulnerability the protection area is defined. The method of half-life as the Vespa index have allowed to arrive at a precise definition of the vulnerability value in order to delineate the relative preservation area. Mascognaz 1, has a high vulnerability, so the absolute protection zone (ZTA) and the two zones, compared (ZR) and protection (ZP), coincident with the entire extension of the basin extension has been delineated. Mascognaz 2, instead, has a low vulnerability, so all three areas has been identified.

It is applied the method of *cross-correlation.* It does not lead to define a vulnerability class, but only it feedbacks information on response of the springs after a recharge event. The values are very low one or two days in contrast with . the application of the half-life method. In fact, both springs show a very rapid response time probably due to the stream. It is difficult to sustain knowing these new data that the vulnerability of the Mascognaz 2springs is low. In Mascognaz 2 there are a very short transit time in the aquifer from isotopic samples and a high response of the flow rate and conductivity of the spring from cross correlation.

On the other hand the vulnerability assessment made by the cross-correlation for Mascognaz 1, which shows an average value of 1 day, seems correct according to other two methods. With method of half-life, the half-life is approximately 14 days indicating a high vulnerability, and the index Vespa without the whole hydrological year, is 0.84 which is very close to 1, showed a vulnerability changed from medium to high.

Finally the application software for the hydrogeological balance (developed for the calculation of the infiltration parameter in the SINTACS method) has allowed the calculation of the infiltration and run-off on the whole basin area.

The whole basin doesn't feeds the springs in fact the maximum quantity in cubic meters, which comes from springs in a year (1,050 $Mm^3$), this value is less than half calculated by the inverse hydrogeological balance method (2,55 $Mm^3$ yellow + green area (Figura 214)) and it is greater than the contribution of only green area (748.000 $m^3$). Without the use of tracers and geophysical prospecting it is not possible to define the real recharge basin of the springs. As seen by chemical and isotopic analysis, the stream feeds the springs. This means that it is not possible identify the recharge area because the stream probably in some places drains and other feeds the water the aquifer.

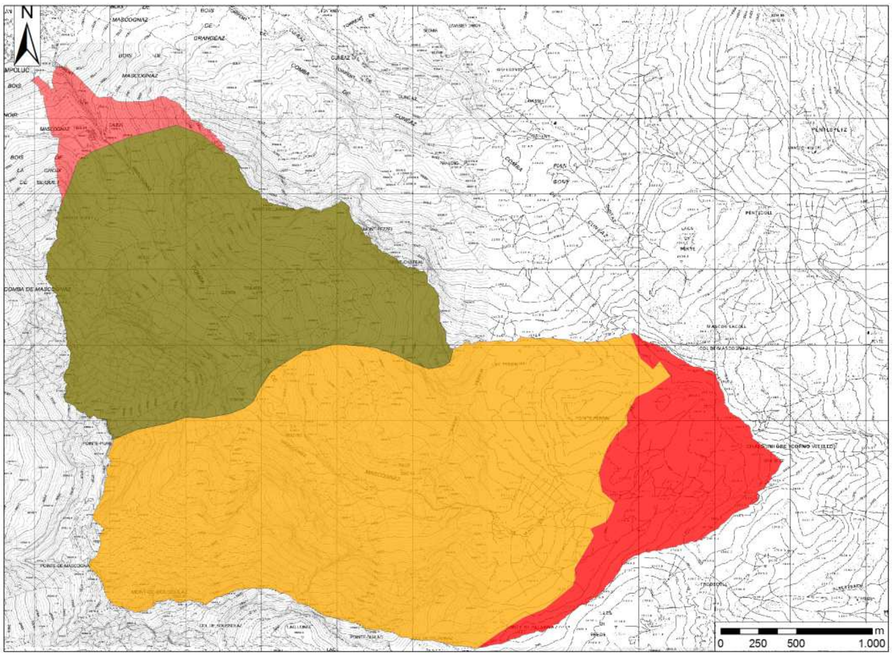


FIGURA 214: BASIN SUBDIVION

It becomes necessary, in view of future study development in the Mascognaz basin, to install downstream of the springs, in the stream bed, a multi-parametric probe. It would allow through the construction of a weir to quantify the relationship between rainfall, springs and stream.
The collaboration with Eng. Bartolomeo Montrucchio and Dr. Gabriele Nocerino also led to the patenting of a new sensor said "Fotochionometro". It allows to measure the density of the snowpack and consequently to estimate the water content in very short time. With this instrument is easy to estimate during the year the SWE. Along with buried rain gauge would constitute a valid instrument and they would used in high-altitude weather stations

FIGURA 215: FIELD ACTIVITY

In these years I analyzed and subsequently computerized through an open source language (Python), three methods for calculating the aquifers vulnerability (SINTACS, DRASTIC and GOD) and one for the calculation of saltwater intrusion vulnerability (GALDIT) in order to apply them more quickly. By the methodology for calculating the SINTACS it was extracted a script used in this thesis to quantify infiltration and runoff.

## 16.2. Guide Lines Introduction

This work defines the guidelines useful to the public administrations and institutions that deal with dynamic mountain springs and melting snow levels. The guidelines indicate a path to take to enhance the protection of the works of uptake and their feeding areas. The processes of power springs in this study was divided in two categories: the first one where the weather station is already present while the second one the station has to be installed.
Thanks to the fund from the Regione Autonoma Valle d'Aosta for the installation of the weather station, it was possible to purchase a series of costly sensors to develop the field experiment.
As a result, the Valley of Mascognaz is one of the most high level instrumented sites in Italian for study the dynamics of the melting snow levels. With the simultaneous study of the springs, it is also able to highlight the most of the phenomena related to the relationships of inflow-outflow that occur in the same area.
Now I present a series of measures that should be required to account for a preliminary study on other mountain basin highlighting what has already been done and what could still be done.

## 16.3. Inflow

A comprehensive study in mountainous areas cannot disregard the phenomena relating to the accumulation of snow in winter and its melting in the period from spring to summer. The snowfall during the winter, do not contribute to runoff in the basin. While during the snowmelt in the spring and summer months their contribution to runoff is often very significant.
The proposed experimental methodology for estimating the quantity of water (SWE), derived from analysis of all equipment installed on the site of Mascognaz, to be applied on a large scale, would be more easily reproduced in other cases.

### 16.3.1. Where the station is ready

So taking into account the standard equipment of a high-altitude weather station has decided to find a methodology that used three tools that worked well in the absence of electric current, as follow:

- Thermometer;
- Snow depth sensor;
- Rain gauge (this can be heated or not).

Furthermore it is necessary to input data, resulting from manual assays by AINEVA (Associazione Interregionale Neve e Valanghe), which is the density, the only parameter capable of being able to discriminate the type of precipitation.

In mountain areas so you can divide the hydrological year into two periods, the first one when the ultrasonic snow depth sensor registers data, and the second one in the remaining period.
In the first case:

$$P[mm] = \begin{cases} if\ T < 1°C; P[mm] = h_{fall} \dfrac{Density(Aineva)}{Density_{water}} \\ if\ T > 1°C\ \ and\ h_{fall} = 0; P[mm] = Rain\ Gauge[mm] \end{cases} \quad (1)$$

To define the content of SWE, resulting from snowfall in high mountain stations, you can easily bring back to (1) where:

- In the case where the temperature is less than the degree, that value was taken as limit of the state transition from rain to snow, the quantity of water is estimated with the data relating to the ultrasonic snow depth sensor (the variation of height in meters snow cause by precipitation) and those mediated by AINEVA observing stations along the entire valley in the study. If you do not run the sampling density, as a result of precipitation, near the station, you must also consider those related to other adjacent valley areas.
- When the temperature is higher than the degree and is not recorded a variation of the height of snow, but the pluviograph a variation, it can be verified two situations:
    - The measured quantity of water derived from melting of snow that fell earlier in the day;
    - The change actually records the occurrence of liquid precipitation (fall and spring). In this case we check the average temperature of the previous days. The possibility to occur a precipitation liquid in response to a snowy during the winter period is rare. Consequently, the error caused by an incorrect interpretation of meteorological data is very low.

In the second case:

$$if\ T > 1\ P[mm] = Rain\ Gauge\ [mm] \quad (2)$$

The situation shown in (2) is that which occurs whenever the ultrasonic snow depth sensor in spring-summer-autumn is not a variation in the height of the snow and then considered only the data on the pluviograph.

### 16.3.2. Where there is no station

If you need to install a new weather station, you must take into account the final purpose of the installation. If this concerns a study in the field of geology and hydrogeology (landslides, springs and streams), a station type allows to determine all the parameters needed for most of these fields consists of:

- Thermometer and hygrometer (to identify the type of precipitation);
- Snow depth sensor ultrasound (to calculate the amount of snow fall in cm);
- Rain gauge Basement (to identify if the compaction of storage resulting from a fusion or by a compaction, and in the period of fusion identify the quantity of water which is transferred to the ground and that consequently infiltrates or runoff).

## 16.4. Out flow

It's very important to studying about springs and streams flow rate, when the groundwater balance of mountain basins has to be estimated. Therefore it is necessary to use probes to measure water levels of springs and streams in side valleys, while in the main valley streams and rivers it is necessary using instrumentation, like hydrometers installed on bridges.
In case of side valleys we can identify two situations:

- Springs and streams are provided with a weir;
- Springs and streams are provided without a weir.

### 16.4.1. Springs and streams are provided with a weir

**Springs:** in this case will be necessary buying a probe to measure at least water level and also to measure temperature and the conductivity. These factors are very important to define vulnerability.
**Streams:** in this case if it's present an enough defined section, a probe similar to that one used to measure springs water level and flow rate, can be installed.

### 16.4.2. Springs and streams are not provided with a weir

**Springs:** in order to supervise springs to measure the flow rate and the relative quantitative of water available, for several uses and to adjust them to European norms, it is necessary to redesign these water picking up works. It's important to construct at least a weir to define its relative flow rate.
Instead, if this is not possible, it is suggested to install a steel tank composed at least by two stainless steel tanks, one for calm water and the other for the charge, separated from a thin weir.
The stainless steel tank is easier to transport in mountains areas, also with helicopter, than the necessary materials to construct a work.
**Streams:** it's difficult to supervise a mountain stream, since an expensive and complex work would have built up. A regular enough stretch of the stream could be identified and arranged with a probe, in order to measure its flow rate.
Thanks to these guide lines, waste of money could be avoided and many useful data about the study of springs, landslides and streams system in mountain areas, would be obtained. Furthermore thanks to these guide lines, how streams suffer the snow fusion in the spring-summery period, can be obtained.

## 16.5. GUIDE LINES FOR THE STUDYING SPRINGS

A complete study about mountain springs cannot abstract from arguments about geologic and geomorphologic characteristics of the river feeding basin.

Moreover chemical and isotopic samplings are necessary, in order to know ties between springs and the stream (if it’s present).

With the isotope analysis is moreover possible to define the time of permanence of the water in the aquifer. Through the application of the cross-correlation it’s possible to specify how much the flow rate or the conductivity suffers the influence of meteoric event. Consequently tracer tests can be executed in order to define the time of travel of waters, inside the aquifer. The obtained data can be compared with data coming from the application of the cross correlation.

It is thought necessary in these guide lines, giving informations about the methodology to adopt, according to input needed data, trying to estimate the present methodologies in literature to assess springs vulnerability.

The methodology of half maximum spring discharge, that is widely employed for the delineation of the safeguard areas needs a only single parameter: the flow rate in connection with time.

Mainly there are three issues to consider:

- Presence of false floods that causes a modification of the curve of exhaustion of the spring;
- Feeding spring effects from the stream, like the case of Mascognaz 2. In this case the application of the methodology is not recommended. That’s why the stream alters the exhaustion curve, and extends the half maximum spring discharge half time;
- Perennial springs presence: a shift towards the low of the ydrogram of the spring must carry out, considering as zero the time that the flow rate spends to reach the minimum value of the considered hydrologic year.

The VESPA index, being an innovative methodology, still demands a calibration of the model, above all about the definition of the vulnerability classes. It is simple to apply and it does not introduce criticality, since it has been developed to analyze Alpine springs.

There are several input data for the model (water level, temperature and conductivity) that needed to measure by probe.

Previous studies in the field indicated that there is not a methodology that can be used in all situations. Assessment of vulnerability of springs is complex and is dependent upon essentially from the surrounding conditions such as duration of precipitation, temperature, humidity, wind velocity, as well as the character of hydrogeology.

Thanks to all these steps, the characterization of the spring from a quantitative and qualitative point of view, can be evaluated, analyzing in details flow rate and vulnerability.